

REMARKS

Claims 7 and 33-65 are presently pending in this application.

By way of review, the pending application is directed to a non-volatile optical system for recording and reading information, based on reorientation of an isomerizable material included in a storage medium. In an embodiment, the system uses two light sources and a storage medium which includes a polymer material doped with isomerizable azobenzene molecules. The azobenzene molecule has two isomers, the stable trans isomer and the unstable cis isomer. One of the two light sources emits coherent light with a wavelength band around red wavelength (647 nm), and the other light source emits light with a wavelength band around blue wavelength (442 nm). The trans isomer state of azobenzene molecules can not absorb the red light, while the cis isomer state can absorb this light and as a result isomerize (transform) to the trans isomer state. Similarly the cis isomer state of azobenzene molecules can not absorb the blue light, while the trans isomer state can absorb this light and as a result isomerize to the cis state. The unstable cis isomers can also isomerize to the trans isomer through thermal relaxation.

Using the above described apparatus a non-volatile grating is formed for recording information [see, e.g., ¶¶ 24-27, 31-33, and 38]. During the process of recording, the system irradiates the storage medium with patterned s-polarized light from the red light source and uniform p-polarized light from the blue light source. The pattern of the light from the red light source is representative of the information to be recorded and includes dark fringes in a first set of locations and bright fringes in a second set of locations. Under normal conditions most of the azobenzene molecules that are doped in the polymer matrix reside in the stable trans isomer state. When the storage medium is irradiated with red wavelength light, the trans isomer molecules do not absorb this light. But when the storage medium is irradiated with blue wavelength light, those trans isomers which are not oriented perpendicular to the polarization of the blue light absorb the blue light, and undergo the transition to the cis state. As it happens, in the bright fringes, the newly formed cis isomers absorb the red wavelength light and isomerize back to the trans state. If the trans isomers are oriented with their dipole orientation perpendicular to the polarization direction of the blue light, they can not absorb the blue light and remain in the reoriented trans state. Thus only

those trans isomers which are still not oriented perpendicular to the polarization of the blue light undergo the transition to cis isomers. The above transformations between the trans and cis isomers in the bright fringes stops when all molecules are in the trans isomers state with their dipole axes perpendicular to the polarization direction of the blue light. These isomers are not disturbed by light from either of the two light sources. In the dark fringes, on the other hand, since the cis isomers are not irradiated with red light, they can only isomerize back to the trans isomers through the slower process of thermal isomerization..

The next step in the process is the removal of both the red and the blue light. As a result, the cis isomers in the location of the dark fringes thermally relax into trans isomers which are randomly oriented. In the resulting storage medium, in a first set of locations (i.e., the location of bright fringes) substantially all isomers are trans isomers oriented perpendicular to the p-polarization of blue light while in a second set of locations (i.e., the location of dark fringes) some isomers are trans isomers oriented perpendicular to the p-polarization of the blue light while other isomers are randomly oriented trans isomers. The distinction between the orientation of the trans isomers in the two types of locations constitutes the non-volatile recorded grating. Moreover, when read with the same red wavelength light, this non-volatile grating is not erased, because the trans isomer molecules do not absorb red light. The grating can only be erased by irradiating the storage medium with circularly polarized blue wavelength light.

Claims Rejections – 35 USC § 103

3. Claims 7, 33-40, 42-57 and 59-65 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Wu et al., “Transient biphotonic holographic grating in photoisomerizative azo materials”, Phys. Rev. B, Vol. 57(7) pp. 3874-3880 (2/98) (hereinafter Wu-57), in view of Natansohn et al., “Azobenzene containing polymers: digital and holographic storage”, Technical Report 19960924 052 US Navy (9/96), Jager et al., “Bicolor surface relieves in azobenzene side chain polymers”, Appl. Opt., Vol. 40(11) pp. 1776-1778 (4/01), Hattemer et al., “synthesis and characterization of novel multifunctional materials obtained via reactive precursor polymers”, Macromol., Vol. 33 pp. 1972-1977 (2000) and “Polymer Chemistry: the glass transition” updated

7/11/000. <http://faculty.uscupstate.edu/llever/Polymer%20Resources/GlassTrans.htm>. (hereinafter Polymer Chemistry). Specifically, the Office Action states that

it would have been obvious to one skilled in the art to modify the examples of [Wu-57], to make a stable grating, similar to that of Jager ..., by using PVA and PMMA with high Tg temperatures, such as 85 degrees C and the 105 degrees C taught by [Polymer Chemistry], to make the gratings more stable based upon the teachings of Natansohn ... and Hattemer ..., that useful Tg are within the range of 60-194 degrees C and that higher Tg prevent the reorientation of the azo dyes (page 4).

Applicants, however, submit that neither Wu-57, nor its combination with the cited references, teach or suggest every element of the claimed invention. Moreover, Wu-57 can not be combined with Jager, Natansohn, or Hattemer, because Wu-57 uses a different type of storage material and relies on a different storage mechanism compared to Jager, Natansohn and Hattemer.

In contrast to the apparatus and methods described above and in the presently pending application, Wu-57 teaches a four-wave mixing setup to generate a transient (volatile) biphotonic holographic grating. The four-wave mixing setup requires a total of four beams, i.e., three red beams (I_a , I_b , and I_c) and one blue beam (I_l) to be used all the time in order to generate the signal I_s (Fig. 4, P. 3877). However, Applicant's invention uses two red beams and a blue beam (total three beams). As soon as the grating starts to form in the storage medium, an induced diffraction signal I_s is generated. Wu-57 teaches the use of slides coated with either PMMA or PVA polymers doped with mono-azobenzene molecules (col. 2, p. 3876), and reports a transient (i.e., volatile) grating, based on redistribution of the cis isomers (Abstract; col. 2, p. 3875; col. 2, p. 3878). While the specific types of azobenzene molecules used in Wu-57 have good trans-cis photoisomerization property, they show no, or very little, molecular reorientation property as concluded in his paper based on both theory and experiment (col. 1, p. 3879).

Jager presents "results of experiments with two-color holography on an azobenzene polymer" (Abstract). Jager's system discloses glass slides coated with Azobenzene side-chain polymers (SCP) (p. 1776) in contrast to the azobenzene doped polymers of the claimed present invention. Jager inscribes the film with two s-polarized beams from a laser at 645 nm. Jager also illuminates the film homogeneously with an argon-ion laser beam at 488 nm that was either s or p polarized (id.) As a result, Jager observes a surface grating resulting from periodic surface reliefs

(Abstract; col. 2, p. 1777; Fig. 4) in contrast to the non-volatile reorientation grating of the claimed present invention.

Natansohn presents utilizing azo-benzene containing polymers for digital and holographic storage (Abstract). Natansohn, similar to Jager, utilizes Azobenzene side-chain polymers (Scheme 1). Natansohn irradiates the medium with green and blue lights of an argon laser (p. 247), and utilizes photo induced birefringence for digital storage (page 238), and photoisomerization to create surface gratings for holographic storage (Abstract; pp. 246-47) again in contrast to the non-volatile reorientation grating of the pending claims.

In the case of azopolymers used by Jager and Natansohn – azobenzene molecules are chemically bonded to the polymer claims forming a surface relief grating due to the polymer mass transportation induced (there are many reports regarding this kind of study). However, the present invention uses azobenzene-doped polymers having no chemical bonding between the azobenzene and the polymer.

Polymer Chemistry teaches glass transition in polymers and lists the glass transition temperatures for various polymers, including PVA and PMMA. It does not suggest, disclose or teach any methods related to holographic recording.

Hattermer describes the synthesis of a new class of high Tg multifunctional photorefractive polymers (Abstract; scheme 2). It reports the formation of photorefractive (PR) and isomerization gratings (col. 1, p. 1976) in contrast to the non-volatile reorientation grating of the pending claims.

Applicants contend that none of the five cited references, either individually or in combination, teach or suggest every element of the claimed invention. Specifically, neither Wu-57, nor any combination of Wu-57 with the cited references, teaches or suggests a system in which

upon removal of the light from the first coherent light source and the second light source, the storage medium form[s] a non-volatile orientation grating at a temperature below a glass transition temperature of the polymer material, the storage medium including the polymer material doped with the plurality of azobenzene molecules that in the first plurality of locations are trans isomers oriented essentially perpendicular to the p-polarization [of the second light source], and in the second plurality of locations comprise

of the first subset that are trans isomers oriented essentially perpendicular to the p-polarization and the second subset that are trans isomers oriented randomly
as recited in pending claim 7. Instead Wu-57 relies on the four-wave mixing setup explained above. While the claimed invention recites removing both the red and the blue light sources, Wu-57 at most considers turning off the short wavelength light (Fig. 5), and nowhere does it teach or suggest removing the red light irradiating the medium. None of the other four cited references supply that which Wu-57 is missing regarding the removal of the light sources.

In addition, none of the cited references teach or suggest forming a non-volatile orientation grating based on the orientation of the trans isomers, as recited in pending claim 7. Instead, Wu-57 relies on creating a transient (volatile) population grating based on redistribution of the cis isomers; Jager and Natansohn, create surface gratings, Hattemer teach photorefractive (PR) and isomerization gratings, and Polymer Chemistry does not teach any type of storage methods.

Despite what the Office Action states, the system in Wu-57 cannot result in the recited invention, simply “by using PVA and PMMA with high Tg temperatures.” In fact, Wu-57 does utilize PVA and PMMA polymers (col. 2, p. 3876), and Tg is an intrinsic property of these polymers. Even if Wu-57 could change the Tg, as proffered in the Office Action; that would not supply Wu-57 with the claim limitations missing above, i.e., of removing the red light, and forming a non-volatile orientation grating. Thus, even if Wu-57 is combined with Jager, Natansohn, Polymer Chemistry, and Hattemer, the combination will not render the claimed invention unpatentable.

Moreover, Applicants contend that Wu-57 can not be combined with Jager, Natansohn, or Hattemer in the first place, because they differ in their materials and their storage types. Wu-57 uses azo-benzene doped polymers to create a holographic redistribution grating in the bulk of the storage material. Jager and Natansohn, on the other hand, use Azobenzene side-chain polymers. Jager creates a surface relief grating on the surface of the medium, and Natansohn creates digital storage based on photoinduced birefringence and holographic storage based on photoisomerization. Similarly, Hattemer studies a new class of polymers and not azo-benzene doped polymers.

For the reasons stated above, claims 7, 33-40, 42-57 and 59-65 are not obvious in view of Wu-57, Jager, Natansohn, Hattemer and Polymer Chemistry.

4. Claims 7, 33-40, 42-57 and 59-65 have been rejected further under 35 U.S.C. § 103(a) as being unpatentable over Wu-57, in view of Natansohn, Jager, Hattemer, and Polymer Chemistry, further in view of Wu et al., “transient optical modulation with a disperse red 1 doped film”, Appl. Opt., Vol. 39(5) pp. 814-817 (2/00) (hereinafter Wu-39). Specifically, the Office Action states that

[Wu-39] teaches the recording of a biphotonic grating using two s polarized beams from a krypton ion laser (647 nm) which overlap with a s polarized beams of a HeCd laser (442 nm) ...To address the embodiments bounded by the claims, but not anticipated above, the examiner cites [Wu-57] who teaches the use of the red (633 nm) laser for the readout and holds that it would have been obvious to use the same technique in the process rendered obvious by the combination [Wu-57] with Natansohn, Jager, Hattemer, and Polymer Chemistry to determine the diffraction efficiency based upon this laser already being part of the apparatus (pages 5-6)

Applicants submit that Wu-39 does not supply the aforementioned limitations missing from Wu-57 and the other cited references. Moreover, Wu-39 cannot be combined with Jager, Natansohn, or Hattemer.

Wu-39 discloses transient optical modulation properties of a disperse-red-1-doped polymer film by use of four-wave mixing with two-color light (Abstract). Wu-39 irradiates the film with two 647-nm s-polarized laser beams and a 442-nm s-polarized laser beam (col. 1, p. 815) and reports competition between one-photon re-orientation mechanisms and a biphoton component that is due to isomerization mechanisms (col. 2, p. 814).

Contrary to what the Office Action states, Wu-39 discloses an optical modulation system, and not a storage system. Further, Wu-39, similar to Wu-57, uses a four-wave mixing setup (Abstract; col. 1, p. 815) and thus, for the reasons explained above, does not supply the elements missing from Wu-57 and the other cited references.

Moreover, Wu-39, like Wu-57, utilizes a polymer doped with an azobenzene compound. As explained above such a material is different from an SCP utilized by Jager, or Natansohn, or the polymers used by Hattemer. Thus Wu-39 can not be combined with Jager, Natansohn or Hattemer.

For the reasons stated above, claims 7, 33-40, 42-57 and 59-65 are not obvious in view of Wu-57, Jager, Natansohn, Hattemer, Polymer Chemistry and Wu-39.

5. Claims 7, 33-40, 42-57 and 59-65 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Wu-57 and Todorov et al., "Polarization Holography. 1: A new high efficiency organic materials with reversible photoinduced birefringence" App. Opt. Vol. 23(23) pp. 4309-4312, in view of Jager, Hattemer, Choi "effect of temperature on photoinduced reorientation of azobenzene chromophore in the side chain copolymers">Bull. Korean Chem. Soc., Vol. 20(9) pp. 1010-1016 (1999) and Polymer Chemistry. Specifically, the Office action states:

It would have been obvious to one skilled in the art to modify the composition of [Wu-57] by using less of the azo dye to increase the Tg based upon the teaching by Choi, ... and thereby increase the stability as taught by Hattemer ..., Choi ..., with reasonable expectation of forming a grating based upon teaching of Todorov ..., who forms a grating with lower azo dyes concentration with motivation from Jager ..., who teaches stabilized gratings, noting that Tg of PVA and PMMA taught by [Polymer Chemistry] which are in the useful ranges taught by Hattemer (pages 7-8)

Applicants, submit that neither Todorov nor Choi supply the aforementioned limitations missing from Wu-57 and the other cited references. Moreover, neither Choi nor Todorov can be combined with Wu-57.

Todorov discloses the use of a medium containing layers of azo-dye methyl orange introduced into PVA (Abstract). Todorov records to the medium using two plane waves with mutually orthogonal polarizations at 488 nm wavelengths (Ar⁺ laser), and reads the medium using a He-Ne laser beam (col. 2, p. 4311). Todorov is based on a conventional volatile holographic recording configuration which is erased if read with the same wavelength used during recording. As a result, and in order to avoid erasure, recording is performed using one wavelength while reading is performed using another wavelength disparate from the recording wavelength.

Choi teaches the effects of temperature on photoinduced birefringence by using aminonitro-azobenzene side chain polymers and reports a change of the birefringence with increasing the sample temperature under continuous irradiation of excitation light (Abstract).

Contrary to what the Office Action states, Wu-57 can not increase the Tg by applying the teachings of Choi, and even if it could, increasing Tg in Wu-57 will not render the claimed invention obvious. Choi's teachings are related to side chain polymers, while Wu-57 uses polymers doped with azobenzene. While, in Choi, a change in the chemical structure of the SCP changes Tg (Table 1), there is no indication that, in Wu-57 and as the Office Action states, using less of the azo dye in a doped polymer will change Tg. Further changing Tg in Wu-57 will not render the claimed invention obvious. As explained above, Wu-57 at least fails to disclose a system in which

upon removal of the light from the first coherent light source and the second light source, the storage medium form[s] a non-volatile orientation grating at a temperature below a glass transition temperature of the polymer material, the storage medium including the polymer material doped with the plurality of azobenzene molecules that in the first plurality of locations are trans isomers oriented essentially perpendicular to the p-polarization [of the second light source], and in the second plurality of locations comprise of the first subset that are trans isomers oriented essentially perpendicular to the p-polarization and the second subset that are trans isomers oriented randomly

as recited in pending claim 7. Neither Choi nor Todorov supply the above missing limitations, because none of them teach or suggest removing the light sources, or forming a non-volatile orientation grating.

Moreover, neither Choi nor Todorov can be combined with Wu-57, because they either use different materials or use different recording apparatus. Choi uses SCP while Wu-57 uses polymer material doped with the plurality of azobenzene molecules. Todorov, uses a conventional holographic recording configuration in which coherent recording occurs using one wavelength and the reading occurs using another wavelength disparate from the recording wavelength. Wu-57, on the other hand, uses the four-wave mixing mechanism explained above.

For the reasons stated above claims 7, 33-40, 42-57 and 59-65 are not obvious in view of Wu-57, Todorov, Jager, Hattemer, Choi, and Polymer Chemistry.

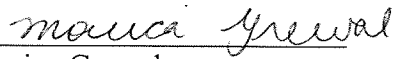
Independent claims 42, 49, and 59 include limitations similar to those mentioned with regards to the independent claim 7 hereinbefore. All other claims depend from one of these independent claims. Therefore, Applicants believe that, at least for the reasons stated above, all rejected claims are patentable over the cited references.

In view of the above Remarks, Applicants submit that the pending application is in condition for allowance, and such action is respectfully solicited. Applicants invite the Examiner to a conference call to further the consideration of the pending claims.

Applicants believe no fee is due with this response. However, if a fee is due, please charge our Deposit Account No. 08-0219, under Order No. 1823430.00121US1 from which the undersigned is authorized to draw.

Respectfully submitted,

Dated: August 4, 2008


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